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PEPD MET LAB

LAB #MS00005945

FAILURE ANALYSIS REPORT

Date 10/17/00

Phone 8-8334

Facility Performance Engine Products Division - Mossville Plant
Department Materials Technology
Attention Rich Bowes
CC Brad Livek

C-10/C-12 Flywheel Housing Crack Analysis

Part Description: C-10/C-12 Flywheel housing.

Engine Information

Engine Series: C-10/C-12
Engine Model No.: C-10/C-12
Engine S/N: N/A
Application: N/A
Engine Hrs/Mileage: N/A
Part Hrs/Mileage: N/A

Dealer: N/A
Claim No.: N/A
Build Date: N/A
Ship Date: N/A

Piece Part Information

Part No.: 6I-4182
Assembly No.: [illegible]
Material Spec(s). & Print Requirements: 1E1047 AP Casting

Date Code(s): N/A
Forger Code / Heat Code: N/A

Reporting Plant: Mossville
Lab Reference No.: #MS0005945

Background: One aluminum C-10/C-12 flywheel housing from a Kenworth open trailer garbage truck was submitted for failure analysis. Although this application has recently produced several, similar failures, these failures have not been observed as frequently in other applications. Because of these failures, the submitted flywheel housing, part number 6I-4182, has since been replaced by 148-1973 on C-12 engines. The new housing has been "beefed up" in several locations for increased strength and stiffness. In addition, the engines were mounted with a front support and two side supports off of the flywheel housing mounts at the rear. The transmission was NOT supported at the rear, but was cantilevered off of the flywheel housing.

Conclusions / Recommendations / Corrective Action:

1. The flywheel failed due to bending fatigue in several different locations.
2. All five cracks initiated in shrinkage cavities.
3. The cracks may have been caused by unanticipated external loading, specific to the garbage hauler application and applied during service.
4. Mounting brackets to fasten the transmission to the frame may prevent fatigue cracking by minimizing the effect of excessive bouncing and torquing associated with this application.
5. The cracks may have been secondary cracks caused by failures of mounting bolts. Field reports indicated several instances of loose or failed bolts, but it is uncertain whether the loose bolts caused the cracking or the cracking caused the bolts to loosen. In addition, bench testing indicated several instances of cracking on hard-mounted housings (without gaskets between the block and the housing).
6. Both loose bolts and hard mounting would increase the effect of external loading on the housing and cause the cracks to form.
7. The failed casting met the minimum requirements of the casting specification, but the additional loading experienced in this application may require higher strength casting.
8. Higher strength fastener with a hard washer may help the situation by allowing higher joint loads (mounting gasket may limit the effect of this recommendation.)

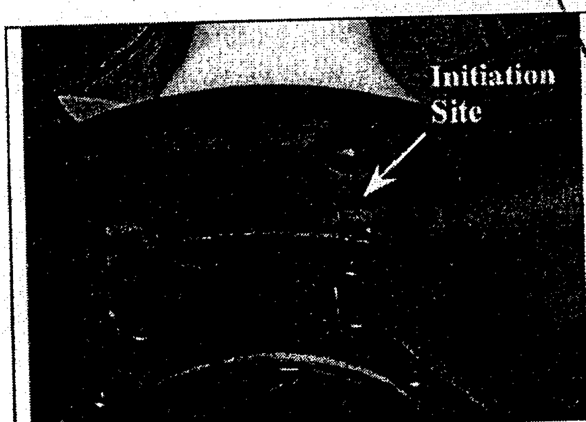

Figure 1: Fatigue crack initiated near the engine mount on top of the housing.

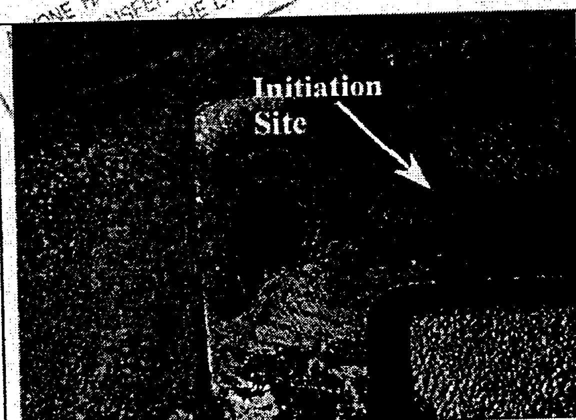

Figure 2: Fatigue crack initiated at corner of the cast slot and propagated to bolt hole on engine mounting face.

Description of Failure: The flywheel housing appeared to fail in several different locations. First, it failed under fatigue loading near the top on the engine side of the housing. The fatigue crack, pictured in Figure 1, initiated near a shrinkage cavity, propagated down the left side housing and arrested in an engine mount bolt hole. A secondary crack appeared to initiate from the same bolt hole propagate away from the engine mount and arrest a short distance from the hole. The fracture was likely caused by excessive external loading. Crack initiation is expected near shrinkage cavities since the porosity acts as an internal notch when loading conditions are excessive. The

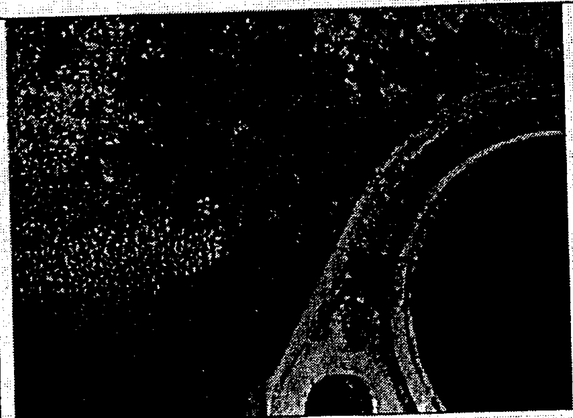

Figure 3: Fatigue crack initiated at starter mounting flange lip.

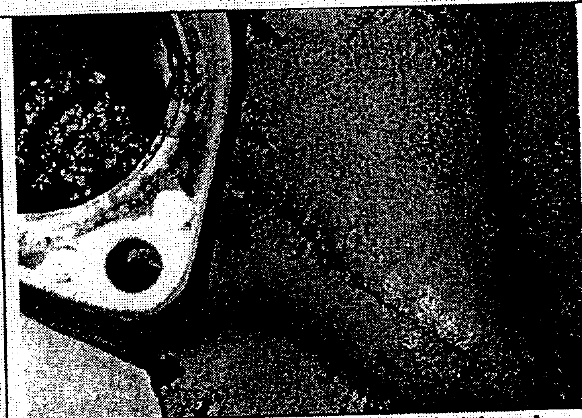

Figure 4: Second fatigue crack initiated at starter mounting flange lip.

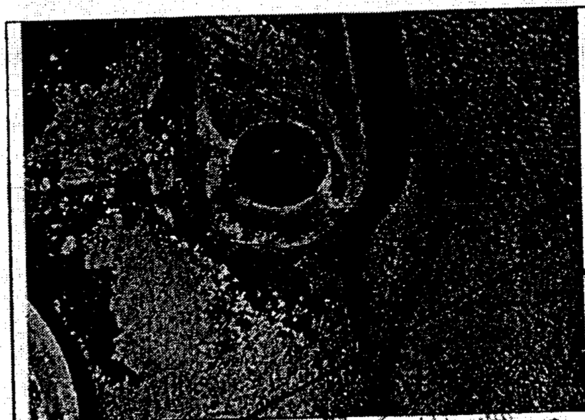

Figure 5: Fatigue crack initiated at lip of engine mounting face.

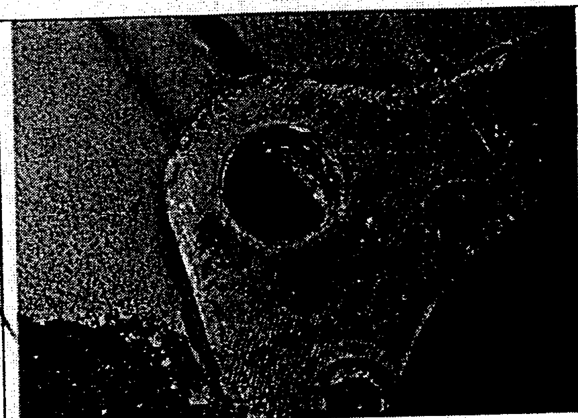

Figure 6: Mashed threads indicate cross threading or over-tightening of mounting bolts.

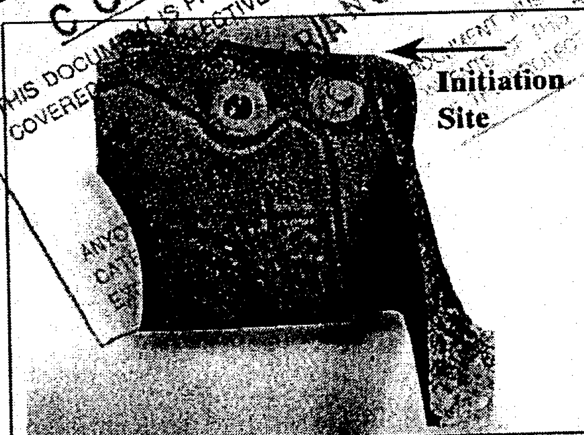

Figure 7: Fracture surface of fatigue crack number 1.

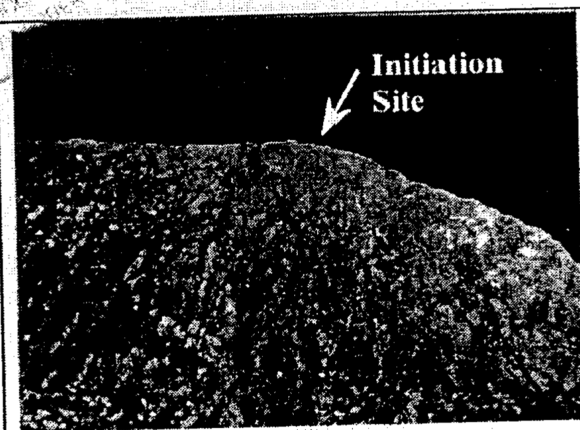

Figure 8: Initiation site of fatigue crack number 1.

remaining cracks, pictured in Figures 3 – 5, also initiated near shrinkage cavities. Although there were some mashed threads from cross-threading there was no deformation of the bolt holes on the transmission mounting face on the back of the flywheel housing. This indicated that the failure was diagnosed before the housing could bounce around enough to damage the bolt holes.

Analysis of the Failure: Visual inspection, SEM analysis, and optical microscopy were used to investigate the failure of one C-12 flywheel housing. The housing was an aluminum casting of 1E1047, which is a high strength alloy similar to Aluminum Association 356. It was solution heat treated and precipitation hardened to a Brinell hardness of 86 (500 kg load, 10 mm ball), which exceeded the minimum hardness specification of 80. The fracture surfaces of the two of the five cracks in the flywheel housing are pictured in Figures 7 – 9. All of the cracks appeared to initiate shrinkage cavities and propagate along the as-cast dendritic structure. Shrink porosity is an internal condition that forms during solidification of the casting (i.e. casting condition). It acts as stress raiser and often becomes an initiation site for fatigue cracks, especially when near the surface. In this case, it appeared as though the specified casting quality was sufficient for the intended application, but the housing was subjected to significant external loading.

Although excessive external loading may have been caused by a failure of the mounting bolts that coupled the flywheel housing with the engine block, it was likely caused by harsh service conditions. Transmission mounting brackets would fasten the transmission to the frame and eliminate the excessive applied loads that may have caused the cracks. Elimination of excessive bouncing and torquing associated with service would reduce loading on the housing and likely prevent fatigue cracking.

It was documented that 100% of the housings with similar cracking characteristics had loose or failed bolts. The bolts were likely loosened by vibrational loading during service. Although insufficient torque during assembly would increase the susceptibility for loose bolts, it is not required to observe the condition. Torque control or use of higher strength bolts would likely reduce the tendency for loose bolts. However, care should be taken not to overcompensate for the under-torquing issue and create an over-torquing issue.

Several design changes have already been implemented to solve the cracking problem. First, the sand cast housing was replaced by a stronger, stiffer permanent mold housing and a design change filled in the cast slot that caused the cracking that was observed on the housing in this report. Second, as engines were inspected the bolts were replaced with higher tensile strength fasteners to increase the clamping force of the joint. Depending on the nature of the gasket the higher clamping force may allow higher joint loads. In general, the pre-load, or clamping force, must always exceed the maximum applied force to avoid fatigue fracture of the bolt. Because of the softness of the aluminum, care should be taken not to over-tighten the new bolts. Third, large, hard washers were used to distribute the load over a larger surface area of the housing. If these recommendations do not prevent future cracking of the flywheel housing, a higher strength casting may be necessary.

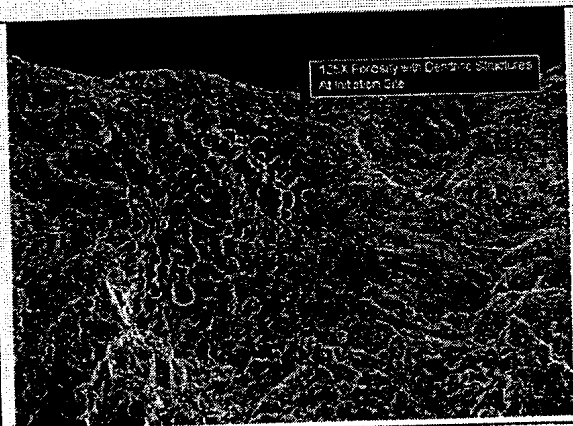

Figure 9: SEM photograph of the fracture surface of crack number 2.

Figure 10: Microstructure of flywheel housing near fracture surface. Dark regions are shrink porosity that contributed to failure of flywheel housing.

The flywheel housing was manufactured from 1E1047, which is a high strength, heat treated aluminum casting alloy. The microstructure, pictured in Figure 10, consisted of aluminum silicon eutectic in a primary, α-aluminum matrix. The dark regions are shrinkage cavities formed that during solidification of the casting. The casting met the minimum requirements specified in 1E1047 and 1E2850. Because shrink porosity contributed to the failure an increase in mechanical properties may be necessary to withstand intense service stresses. Increased mechanical properties would require higher inspection classes and quality grades, such as Class 2, Grade B or A. These castings are premium grades intended for critical, high performance applications. They would have higher inspection criteria, better fatigue strength and fracture toughness, and less porosity and susceptibility to fatigue cracking than the current grade.